



RCA SILICON CONTROLLED-RECTIFIERS

ALL-DIFFUSED SCR's FOR LOW-COST
POWER-CONTROL AND
POWER-SWITCHING APPLICATIONS

2N3668
2N3669
2N3670

RCA-2N3668*, 2N3669*, and 2N3670* are all-diffused, three-junction, silicon controlled-rectifiers (SCR's[▲]). They are intended for use in power-control and power-switching applications requiring a blocking voltage capability of up to 400 volts and a forward-current capability of 12.5 amperes (rms value) or 8 amperes (average value) at a case temperature of 80°C.

The 2N3668 is designed for low-voltage power supplies, the 2N3669 for direct operation from 120-volt line supplies, and the 2N3670 for direct operation from 240-volt line supplies.

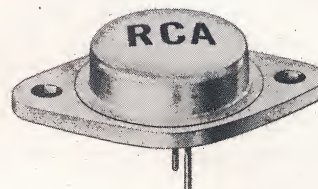
* Formerly Dev. Types TA2621, TA2598, and TA2618, respectively.

▲ The silicon controlled-rectifier is also known as a reverse-blocking triode thyristor.

FEATURES

- Designed especially for high-volume systems
- All-diffused construction -- assures exceptional uniformity and stability of characteristics
- Multi-diffusion process -- permits precise control of individual junction parameters
- Direct-soldered internal construction -- assures exceptional resistance to fatigue
- Symmetrical gate-cathode construction -- provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- All-welded construction and hermetic sealing
- Low leakage currents, both forward and reverse
- Low forward voltage drop at high current levels
- Low thermal resistance

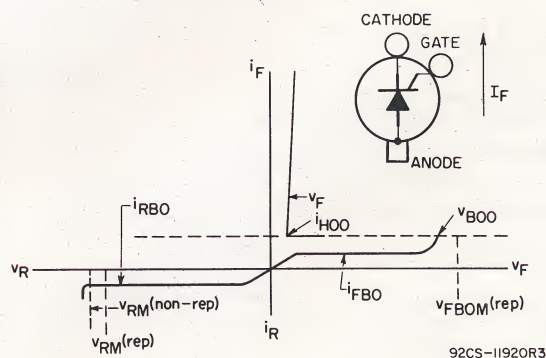
Information furnished by RCA is believed to be accurate and reliable. However, no responsibility is assumed by RCA for its use; nor for any infringements of patents or other rights of third parties which may result from its use. No license is granted by implication or otherwise under any patent or patent rights of RCA.



JEDEC No. TO-3

2N3668	For Low-Voltage Power Supplies
2N3669	For 120-Volt Line Operation
2N3670	For 240-Volt Line Operation

TYPICAL E-I CHARACTERISTIC OF SILICON CONTROLLED-RECTIFIER



RADIO CORPORATION OF AMERICA
Electronic Components and Devices
Harrison, N. J.

Trademark(s) ® Registered
Marca(s) Registrada(s)

2N3668, 2N3669, 2N3670 12-64
Printed in U.S.A.

**Absolute-Maximum Ratings, for Operation with Sinusoidal AC Supply Voltage
at a Frequency between 50 and 400 cps, and with Resistive or Inductive Load**

RATINGS	CONTROLLED-RECTIFIER TYPES			UNITS
	2N3668	2N3669	2N3670	
Transient Peak Reverse Voltage (Non-Repetitive), v_{RM} (non-rep) ^a	150	330	660	volts
Peak Reverse Voltage (Repetitive), v_{RM} (rep) ^b	100	200	400	volts
Peak Forward Blocking Voltage (Repetitive), v_{FBOM} (rep) ^c	600	600	600	volts
Forward Current:				
For case temperature (T_C) of +80°C, and unit mounted on heat sink —				
Average DC value at a conduction angle of 180°, I_{FAV} ^d	8	8	8	amperes
RMS value, I_{FRMS} ^e	12.5	12.5	12.5	amperes
Peak Surge Current, i_{FM} (surge) ^f :				
For one cycle of applied voltage	200	200	200	amperes
For more than one cycle of applied voltage	See Fig.2	See Fig.2	See Fig.2	
Peak Forward Gate Current, i_{GKM} ^g	2	2	2	amperes
Peak Gate Voltage:				
Forward, v_{GKM} ^h	10	10	10	volts
Reverse, v_{KGM} ^h	5	5	5	volts
Gate Power:				
Peak, P_{GM} ⁱ	5	5	5	watts
Average, P_{GAV} ^k	0.5	0.5	0.5	watt
Temperature:				
Storage, T_{stg}	-40 to +125	-40 to +125	-40 to +125	°C
Operating (Case), T_C	-40 to +100	-40 to +100	-40 to +100	°C

^a Temperature reference point is within 1/8" of the center of the underside of unit.

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)

CHARACTERISTICS	CONTROLLED-RECTIFIER TYPES									UNITS
	2N3668			2N3669			2N3670			
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Forward Breakover Voltage, v_{BOO}^m : At $T_C = +100^{\circ}C$	100	-	-	200	-	-	400	-	-	volts
Peak Blocking Current, at $T_C = +100^{\circ}C$, V_{FBO} and V_{RBO} = Rated Values:										
Forward, I_{FBOM}^n	-	0.2	2	-	0.25	2.5	-	0.3	3	ma
Reverse, I_{RBOM}^p	-	0.05	1	-	0.1	1.25	-	0.2	1.5	ma
Forward Voltage Drop, v_F^q :										
At a Forward Current of 25 amperes and a $T_C = +25^{\circ}C$ (See <i>Fig.7</i>).	-	1.4	1.8	-	1.4	1.8	-	1.4	1.8	volts
DC Gate-Trigger Current, I_{GT}^r :										
At $T_C = +25^{\circ}C$ (See <i>Fig.6</i>).....	1	25	40	1	25	40	1	25	40	ma (dc)
Gate-Trigger Voltage, V_{GT}^s :										
At $T_C = +25^{\circ}C$ (See <i>Fig.6</i>).....	-	1.5	2	-	1.5	2	-	1.5	2	volts (dc)
Holding Current, i_{HOO}^t :										
At $T_C = +25^{\circ}C$	0.5	20	50	0.5	20	50	0.5	20	50	ma

RATING CHART (CASE TEMPERATURE)

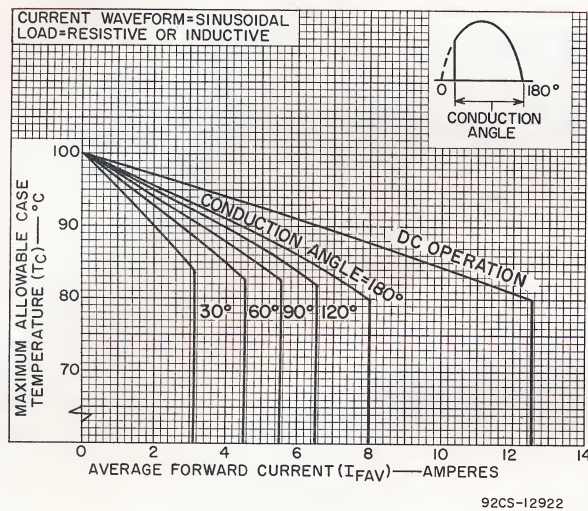


Fig.1

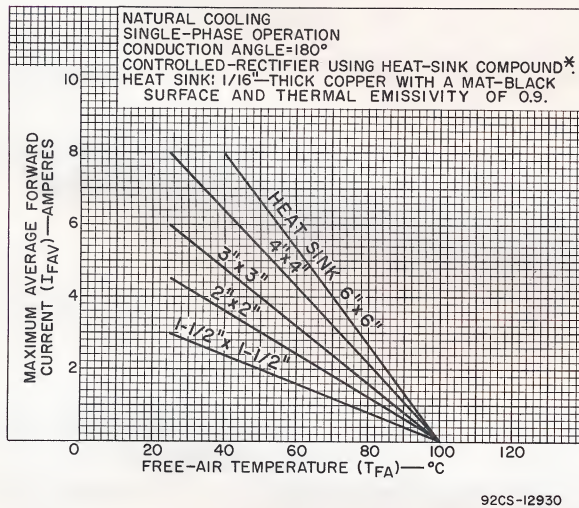
NATURAL-AIR COOLING OPERATION
GUIDANCE CHART

Fig.3

POWER DISSIPATION CHART

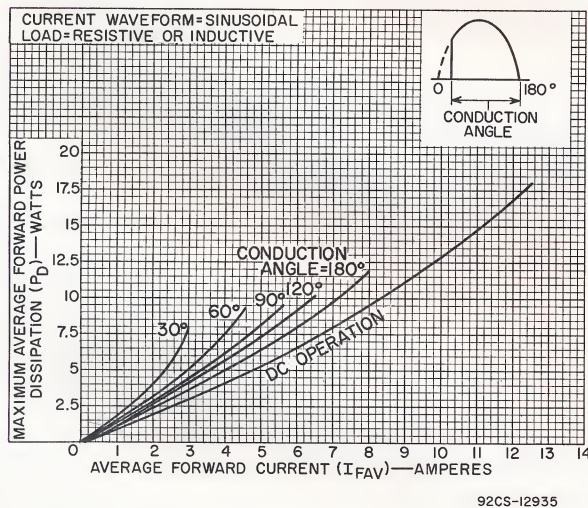


Fig.5

SURGE CURRENT RATING CHART

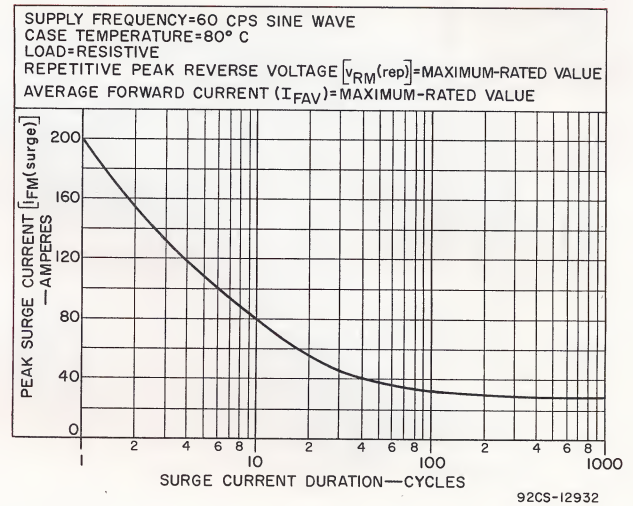


Fig.2

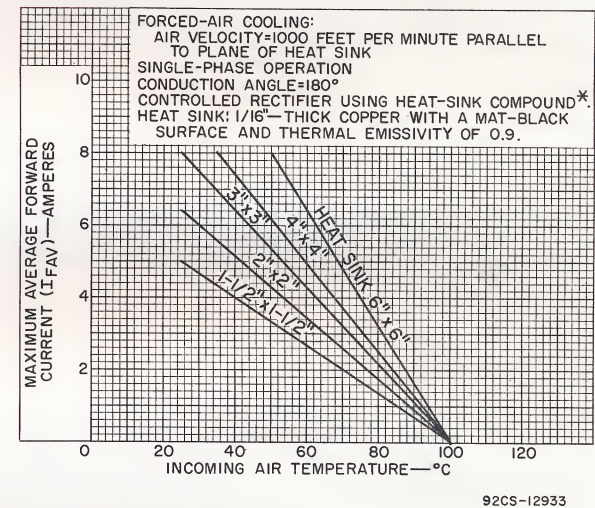
FORCED-AIR COOLING OPERATION
GUIDANCE CHART

Fig.4

GATE-TRIGGER CHARACTERISTICS

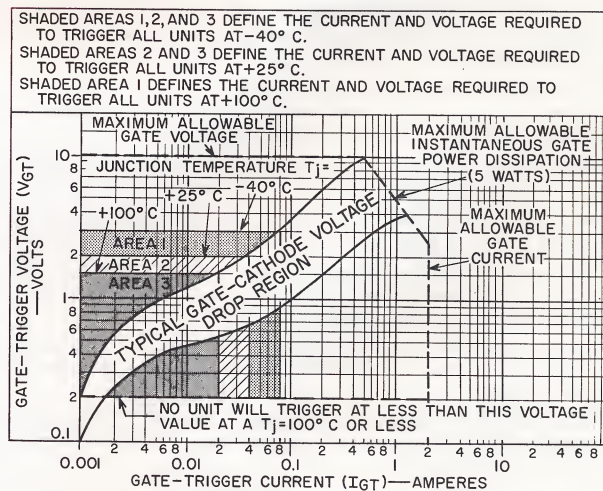


Fig.6

* Dow Corning 340 Silicon Heat Sink Compound, or equivalent.

FORWARD CHARACTERISTICS

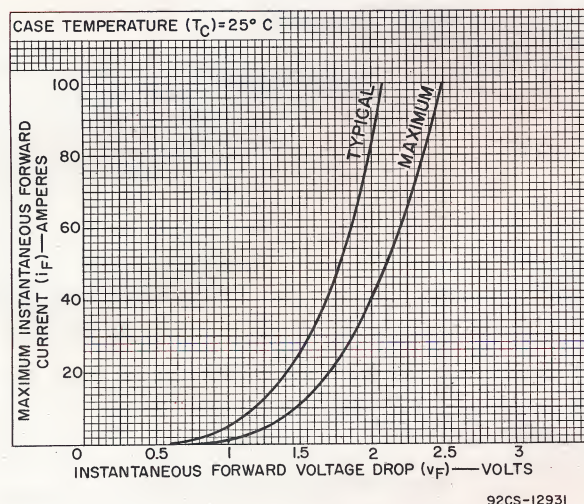
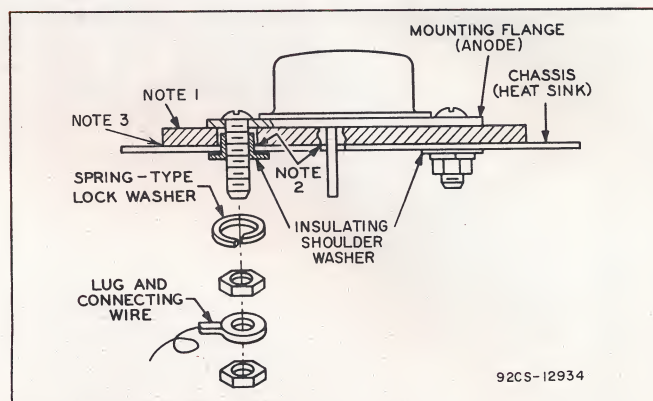
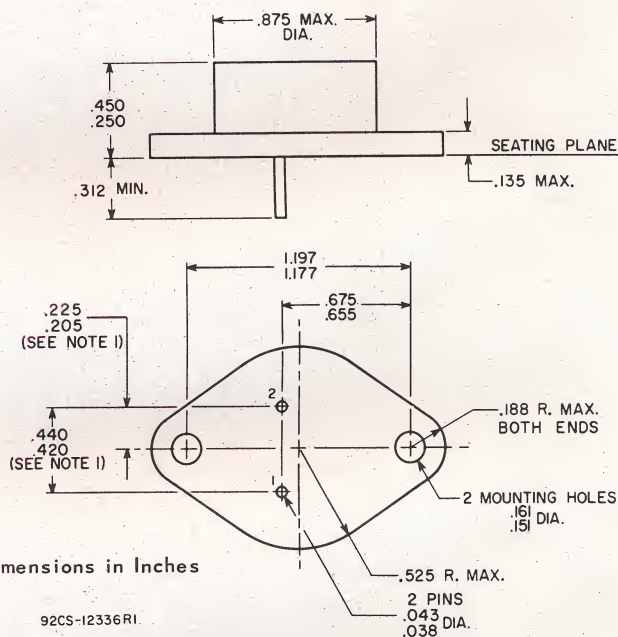


Fig.7

CONTROLLED-RECTIFIER TERMS, SYMBOLS, AND DEFINITIONS

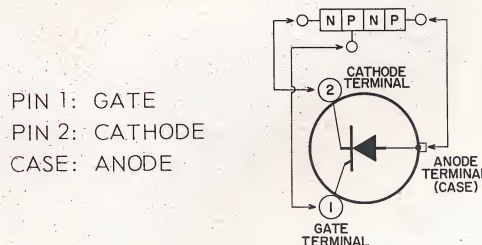
- a **Transient Peak Reverse Voltage (Non-repetitive) - $v_{RM(non-rep)}$** - The maximum value of negative (reverse-blocking) voltage which may be applied between the anode and cathode for not more than 5 milliseconds when the gate is open (gate voltage is zero or negative with respect to cathode).
- b **Peak Reverse Voltage (Repetitive) - $v_{RM(rep)}$** - The maximum instantaneous value of negative (reverse-blocking) voltage which may be applied repetitively between the anode and cathode when the gate is open.
- c **Peak Forward Blocking Voltage - $v_{FBOM(rep)}$** - The maximum instantaneous value of positive (forward-blocking) voltage which may be applied repetitively between the anode and cathode when the gate is open.
- d **Average Forward Current - I_{FAV}** - The average (dc) value of the current flowing from anode to cathode in the device.
- e **RMS Forward Current - I_{FRMS}** - The RMS value of the current flowing from anode to cathode in the device.
- f **Peak Surge Current - $i_{FM(surge)}$** - The maximum total instantaneous value of forward current which may be imposed during one forward half-cycle with the device operating within its specified maximum voltage, average-forward-current, gate-power, and temperature ratings in a single-phase circuit with 60-cps supply and resistive load. The peak surge current may be repeated after sufficient time has elapsed for the device to return to pre-surge thermal equilibrium conditions.
- g **Peak Forward Gate Current - i_{GKM}** - The maximum instantaneous value of the current which may flow between gate and cathode.
- h **Peak Gate Voltage - v_{GKM} or v_{KGM}** - The maximum instantaneous value of voltage, either forward or reverse, which may be applied between gate and cathode.
- i **Peak Gate Power - P_{GM}** - The maximum instantaneous power dissipated between gate and cathode.
- k **Average Gate Power - P_{GAV}** - The average power dissipated between gate and cathode.
- m **Forward Breakover Voltage - v_{BOO}** - The value of positive anode voltage at which a controlled rectifier switches into the conducting state when the gate is open.
- n **Peak Forward Blocking Current - I_{FBOM}** - The maximum value of the forward blocking current of a controlled rectifier with gate open.
- p **Peak Reverse Blocking Current - I_{RBOM}** - The maximum value of the reverse blocking current of a controlled rectifier with gate open.
- q **Forward Voltage Drop - v_F** - The instantaneous voltage drop across a controlled rectifier at a given instantaneous forward current i_F .
- r **Gate-Trigger Current - I_{GT}** - The gate current required to trigger a controlled rectifier operating at a specified temperature when the anode is at a potential of +6 volts with respect to the cathode.

SUGGESTED INSULATED MOUNTING ARRANGEMENT

DIMENSIONAL OUTLINE
JEDEC No. TO-3

NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050 TO .055 BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT WILL BE MADE AT SEATING PLANE.

TERMINAL DIAGRAM



- s **Gate-Trigger Voltage - V_{GT}** - The gate-to-cathode voltage required to trigger a controlled rectifier operating at a specified temperature when the anode is at a potential of +6 volts with respect to the cathode.
- t **Holding Current - i_{HO}** - The instantaneous value of forward current i_F below which a controlled rectifier with its gate open returns to its forward blocking state.

Application note

APPLICATION OF RCA SCR'S TO SPEED CONTROL OF UNIVERSAL MOTORS

By: J.V. YONUSHKA

INTRODUCTION

This Note describes the application of RCA silicon controlled rectifiers to speed-control circuits for fractional horse-power, series wound, universal motors used in such applications as portable hand tools, winding machines, processing and material handling machines and home appliances.

Silicon controlled rectifiers have been widely accepted for power control applications in industrial systems where high performance requirements justified the economics of the application. Historically, in the commercial high-volume market, economic considerations precluded the use of the SCR. However, with the development of a family of SCR's by RCA (designed specifically for mass production economy and rated for 120- and 240-volt line operation), speed controls for fractional horse power universal motors can be designed to provide good performance, maximum efficiency and high reliability in compact and facile packages.

The control circuits presented herein are typical of the many possible circuits applicable for universal motor speed control. Each circuit has been selected to compare performance against component cost. A general description and the typical characteristics of universal motors are given. Speed-control using phase angle variation

is discussed and schematic diagrams are described. The advantages and limitations of each circuit are contrasted. A method to select an SCR for a particular circuit configuration and a given motor horse power rating is presented in the last section.

GENERAL INFORMATION

Most fractional horse power motors are series wound as shown in Figure 1. The universal motor,

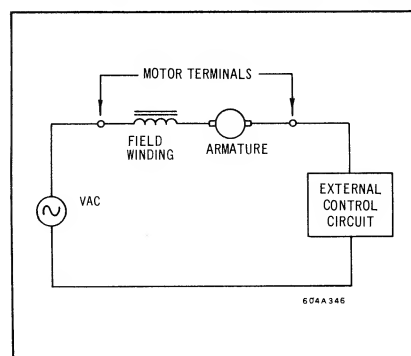


FIGURE 1 SERIES WOUND
UNIVERSAL MOTOR

widely used for a large number of applications, is specifically designed to operate on a.c. or d.c. and can be considered as a special type of series motor. It is basically a d.c. motor with a.c. performance characteristics which are equivalent. It is not possible to have identical performance characteristics of a universal motor

operating on d.c. and on all distribution frequencies. Because most domestic applications today are for 60 cps power, universal motors are usually designed to give optimum performance characteristics at this frequency. Most universal motors will run faster at a given d.c. voltage than at the equal 60 cps a.c. voltage.

The field winding of a universal motor, whether distributed or lumped (salient pole), is in series with the armature and external circuit. Current flowing through the field winding produces a magnetic field which cuts across the armature conductors. The opposing field set up in the conductor by armature current subjects the individual conductors to a lateral thrust which produces armature rotation.

The a.c. operation of the universal motor is achieved by the nature of its electrical connections. Since the a.c. source voltage reverses every half-cycle, the magnetic field produced by the field winding reverses its direction in conjunction with the applied a.c. voltage. Because the armature windings are in series with the field windings through its brushes and commutating segments, the current through the armature windings also reverses. With both the magnetic field and armature current reversed, the lateral thrust on the armature windings remains in



The Most Trusted Name in Electronics

INFORMATION FURNISHED BY RCA IS BELIEVED TO BE ACCURATE AND RELIABLE. HOWEVER, NO RESPONSIBILITY IS ASSUMED BY RCA FOR ITS USE; NOR FOR ANY INFRINGEMENTS OF PATENTS OR OTHER RIGHTS OF THIRD PARTIES WHICH MAY RESULT FROM ITS USE. NO LICENSE IS GRANTED BY IMPLICATION OR OTHERWISE UNDER ANY PATENT OR PATENT RIGHTS OF RCA.

the same direction.

As the armature rotates through the magnetic field, a voltage opposite to the impressed voltage is induced in the individual armature conductors. In half-wave operation, during the non-conducting half-cycle of the SCR, the rotating armature still produces a counter EMF due to the residual magnetism of the field poles. Counter EMF produced in the armature conductors is therefore proportional to motor speed. In some of the applications described in this note, the counter EMF of an operating motor is used as a means of providing speed regulation for changing shaft loads.

The resultant current flowing through an operating motor armature depends upon the difference between the impressed voltage (EMF) and the counter EMF. The current that will flow through a universal motor when it is initially energized will be large because there is no rotation to generate a counter EMF in the armature windings and the starting current will only be limited by the impedance of the armature and field windings. The ratio of peak starting current to peak running current can be as high as 10:1.

The speed of a series motor automatically adjusts itself to such a value that the difference between the impressed voltage and the counter EMF permits enough current to flow to develop the torque required by the load. At very light loads or at no load, the current through the universal motor is small. To maintain a small current through the motor, the counter EMF must be high to have a small difference between impressed voltage and counter EMF. The small current through the motor also results in a weak magnetic field flux since the motor current flowing through the field winding produces the magnetic field flux. The weakened magnetic field flux tends to make the motor speed increase even further to produce the high counter EMF required. Actually, universal motors would tend to "run away" at no loads, however, portable hand tools and universal motors with gear trains offer enough friction and windage losses to limit the no-load speed to a safe value.

When a mechanical load is put on a universal motor, the current must increase correspondingly through the motor to provide the increased torque required by the load. To increase the current through the motor, the difference between impressed voltage and counter EMF must increase. This can only be brought about by a lower counter EMF which results in a decrease in motor speed. Therefore, placing a mechanical load on a universal motor tends to reduce the speed of the motor. For many portable hand tools and universal motors with gear trains, the full load speed is approximately 60 percent of the no-load speed.

The torque developed by a universal motor is a direct result of the magnitude of magnetic field flux and armature current. For fixed mechanical loads, the starting torque of a universal motor is high since the armature current when starting is high. Also at stall conditions, the armature current is large, this results in a large torque. The stall torque of a series motor can be as high as 10 times the continuous rated torque.

Since torque and armature current influence the speed of a universal motor, it is possible under certain operating conditions to vary the impressed voltage and influence the motor's operating characteristics. For increased mechanical loads, increasing the impressed voltage will produce a large armature current and tend to

keep the speed constant. Also, for fixed mechanical loads, increasing the impressed voltage produces a higher armature current to increase the motor speed and keep the torque the same.

The high starting torque, adjustable speed characteristics and small size are distinct advantages of a universal motor over a comparable rated single-phase induction motor. Typical characteristic curves for a universal motor are shown in Figure 2.

SPEED CONTROL

One of the most simple and efficient means of varying the impressed voltage to a universal motor is by controlling the conduction angle of an SCR placed in series with the motor. This phase control technique is illustrated in Figure 3. Since the SCR is a rectifying device, only that portion of the cycle positive at the anode of the SCR at the time of firing is applied to the load. The SCR turns off when the supply line voltage reverses polarity every half-cycle. Because of the d.c. characteristics of a universal motor, using the SCR as a means of varying the impressed voltage to change the motor speed becomes quite practical in half-wave applications. A typical curve showing the variation of motor speed with SCR conduction angle for both half-wave and full-wave impressed motor voltage is shown in Figure 4.

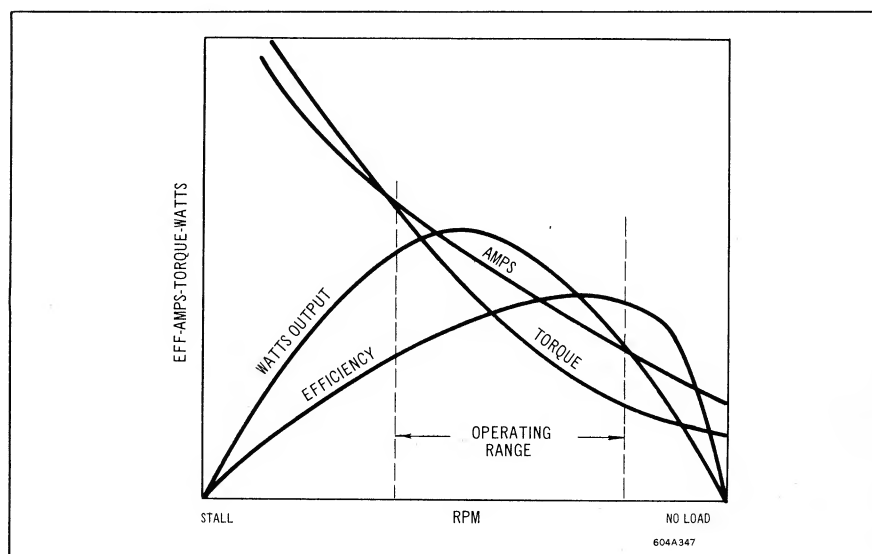


FIGURE 2 TYPICAL PERFORMANCE CURVES OF UNIVERSAL MOTORS

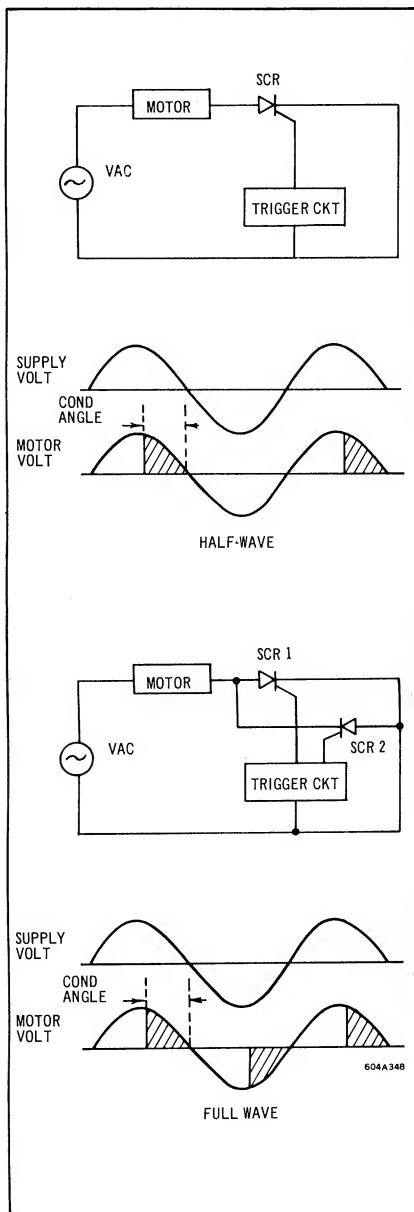


FIGURE 3 VOLTAGE WAVE SHAPES IN AC PHASE CONTROL CIRCUITS

APPLICATIONS

Half-Wave

The circuit of Figure 5 is recommended for applications requiring stable operation at low speeds with fixed loads. This circuit is more advantageous than simple resistance firing circuits since the phase shifting characteristics of the RC network allows firing the SCR beyond the peak of the impressed voltage, resulting in small conduction angles. Thus very slow speeds can be obtained.

On the positive half-cycle of the applied voltage, capacitor C1

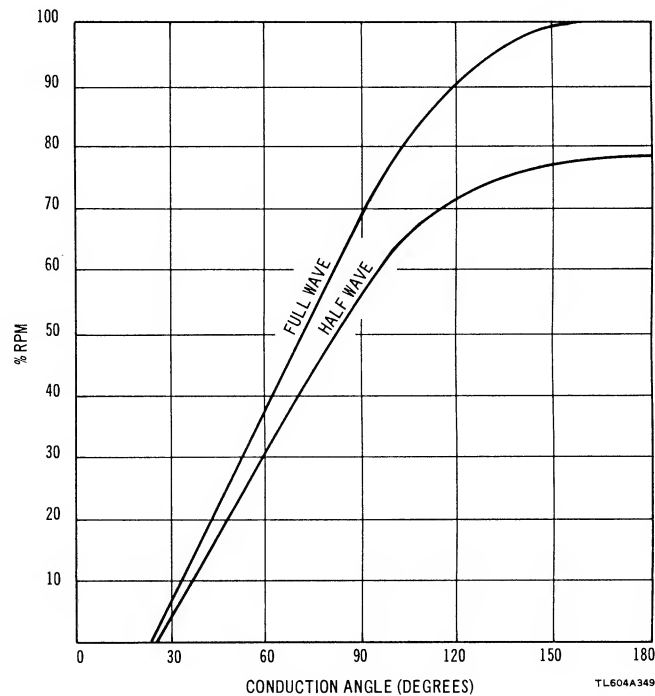


FIGURE 4 TYPICAL PERFORMANCE CURVES OF A UNIVERSAL MOTOR WITH PHASE ANGLE CONTROL

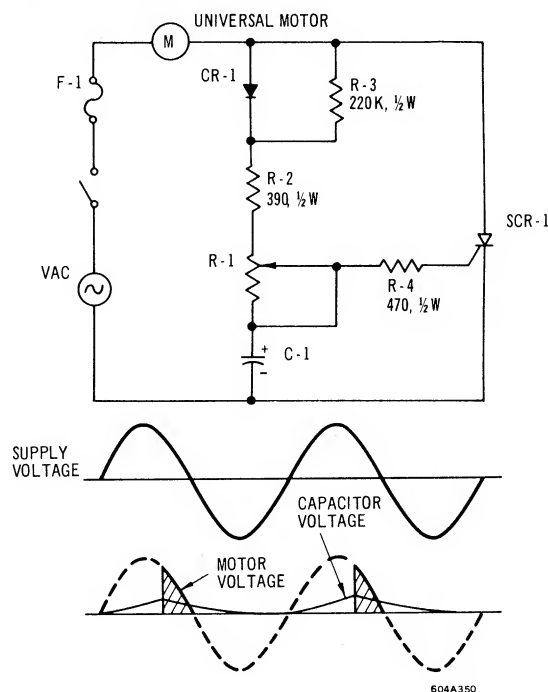


FIGURE 5 HALF-WAVE MOTOR CONTROL, NO REGULATION



VAC	IAC	F-1	CR1	R-1	C-1	SCR1
120V	1A	3AG-1.5A, Quick Act	RCA 1N3755	20K, ½W	8μf, 10V	RCA 2N3528
120V	3A	3AB-3A	RCA 1N3755	20K, ½W	8μf, 10V	RCA 2N3228
120V	7A	3AB-7A	RCA 1N3755	5K, 2W	8μf, 25V	RCA 2N3669
240V	1A	3AG-1.5A, Quick Act	RCA 1N3756	20K, 2W	8μf, 10V	RCA 2N3529
240V	3A	3AB-3A	RCA 1N3756	20K, 2W	8μf, 10V	RCA 2N3525
240V	7A	3AB-7A	RCA 1N3756	10K, 5W	8μf, 25V	RCA 2N3670

TABLE I COMPONENT VALUES FOR FIGURE 5

is charged through network R1, R2 and CR1. When the voltage on C1 exceeds the gate firing voltage of SCR1, the SCR will turn on, applying the remaining portion of the half-cycle to the load. On the negative half cycle, C1 discharges to zero volts through R1, R2 and R3. The delay in firing SCR1 depends upon the time constant network (R1, R2 and C1) which produces a phase shifted gate firing voltage relative to the supply voltage. The amount of phase shift is adjusted by R1. With maximum resistance in the circuit, the RC time constant is longest. This results in a large phase shift with a correspondingly small conduction angle and slow motor speeds. With minimum resistance, the phase shift is small with essentially full line voltage applied to the load, giving maximum speed. It should be noted that this circuit does not provide torque compensation, therefore, care should be exercised to prevent stalling of the motor. Under stall conditions, currents can become excessive as noted previously. The SCR should not be subjected to a stall current greater than a few seconds, unless special design considerations have been included in the system. Circuit values (Fig. 5) for use with the various RCA SCR's are shown in Table 1.

The circuit shown in Figure 6 reduces spread in gate turn-on characteristics. This circuit depends upon the fast switching characteristics of transistors. The phase shift characteristics are still retained to give conduction angles less than 90° through the RC network of R1, R2 and C1. R3 provides turn-on current to the base of Q1 when the voltage on C1 becomes large enough on the positive half-cycle. Base current flowing in Q1 turns Q1 on, supplying base current to Q2. When Q2 turns on it supplies more base current to Q1 providing more regeneration to

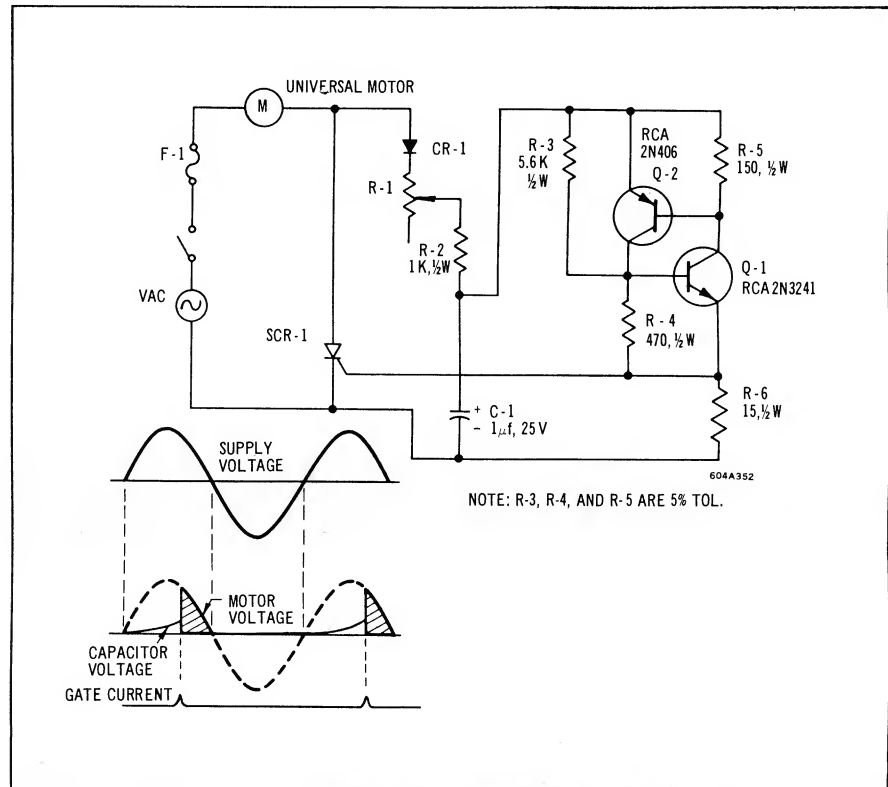


FIGURE 6 HALF-WAVE MOTOR CONTROL, NO REGULATION

VAC	IAC	F-1	CR1	R-1	SCR1
120V	1A	3AG-1.5A, Quick Act	RCA 1N3755	75K, ½W	RCA 2N3528
120V	3A	3AB-3A	RCA 1N3755	75K, ½W	RCA 2N3228
120V	7A	3AB-7A	RCA 1N3755	75K, ½W	RCA 2N3669
240V	1A	3AG-1.5A, Quick Act	RCA 1N3756	150K, ½W	RCA 2N3529
240V	3A	3AB-3A	RCA 1N3756	150K, ½W	RCA 2N3525
240V	7A	3AB-7A	RCA 1N3756	150K, ½W	RCA 2N3670

TABLE II COMPONENT VALUES FOR FIGURE 6

saturate the transistors rapidly. Capacitor C1 discharges through the saturated transistors into the gate of the SCR. When the SCR fires, the remaining portion of the positive half-cycle is applied to the motor. Speed control is accomplished by changing the setting of R1. With the values shown in Figure 6 the threshold voltage for firing the circuit is approximately

8-volts. Maximum conduction angle is approximately 170°. Circuit values (Fig. 6) for use with the various RCA SCR's are shown in Table II.

The control circuit shown in Figure 7 uses the breakdown voltage of a neon lamp as a threshold setting for firing the SCR. The NE-83 neon lamp is specifically designed for handling the high

current pulses required for triggering SCR's. When the voltage on C1 reaches the breakdown voltage of the neon lamp, the lamp fires and C1 discharges through the lamp to its maintaining voltage. At this point, the lamp again reverts to its high impedance state. The discharge of the capacitor from breakdown to maintaining voltage of the neon lamp provides

a current pulse of sufficient magnitude to fire the SCR. Once the SCR has fired, the voltage across the phase shifting network reduces to the forward voltage drop of the SCR for the remainder of the half-cycle. The capacitor discharges through R3 from the maintaining voltage of the neon lamp to zero volts. Higher breakdown voltage of the neon lamp reduces slightly the range of conduction angles. The range of conduction angles of the circuit of Figure 7 is approximately 30° to 150°. The high breakdown voltage of the neon lamp provides excellent noise rejection and prevents erratic firing of the SCR due to brush noises on the voltage supply lines. Circuit values (Fig. 7) for use with the various RCA SCR's are shown in Table III.

A fundamental circuit which is quite effective in providing motor speed control for universal type motors is shown in Figure 8. This circuit makes use of the counter EMF induced into the rotating armature due to residual magnetism of the motor on the half-cycle when the SCR is blocking. Because the counter EMF is a function of speed, it is used as an indication of speed changes for mechanical load variations. The gate firing circuit is a resistance network consisting of R1 and R2. During the positive half-cycle of the source voltage a fraction of the voltage is developed at the center tap of the potentiometer and compared with the counter EMF developed in the rotating armature of the motor. When the bias developed at the gate of the SCR from the potentiometer exceeds the counter EMF of the motor, the SCR fires, applying potential to the motor for the remaining portion of the positive half-cycle. Speed control is accomplished by varying the potentiometer setting from maximum to minimum. If the SCR is fired early in the cycle, the motor operates at high speed since essentially, rated line voltage is applied to the motor. If the SCR is fired later in the cycle, reduced average voltage is applied to the motor with a corresponding reduction in motor speed. On the negative half-cycle, the SCR blocks voltage to the motor. Since the voltage applied to the gate of the SCR is a sine-wave and in phase with the supply voltage, the min-

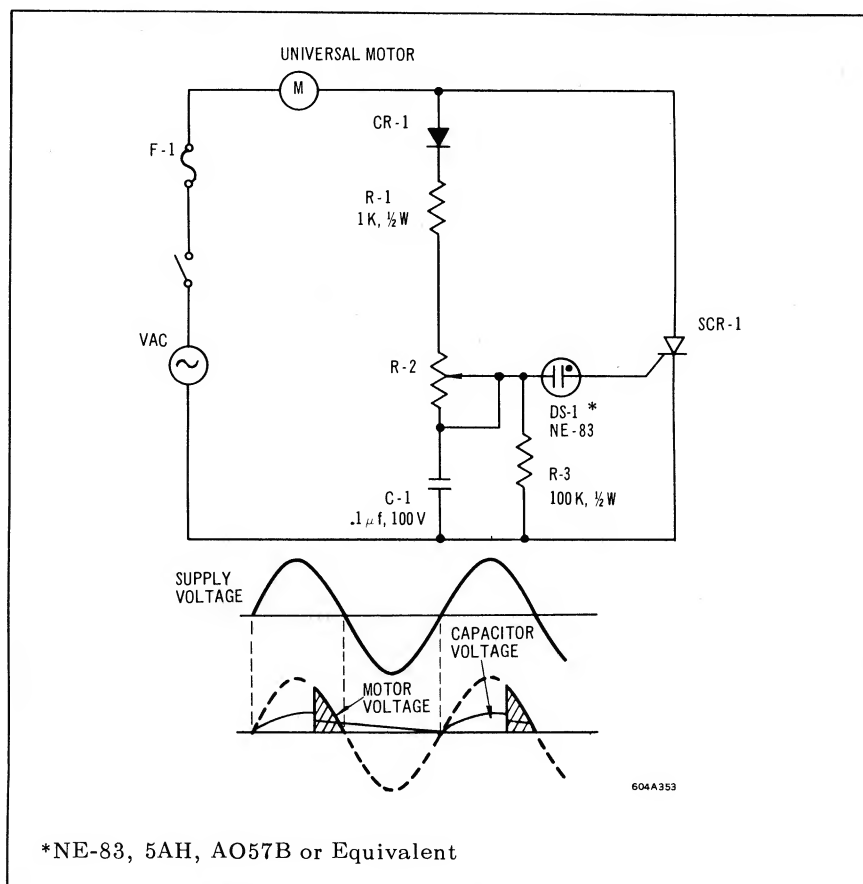


FIGURE 7 HALF-WAVE MOTOR CONTROL, NO REGULATION

VAC	IAC	F-1	CR1	R-2	SCR1
120V	1A	3AG-1.5A, Quick Act	RCA 1N3755	75K, 1/2W	RCA 2N3528
120V	3A	3AB-3A	RCA 1N3755	75K, 1/2W	RCA 2N3228
120V	7A	3AB-7A	RCA 1N3755	75K, 1/2W	RCA 2N3669
240V	1A	3AG-1.5A, Quick Act	RCA 1N3756	100K, 1/2W	RCA 2N3529
240V	3A	3AB-3A	RCA 1N3756	100K, 1/2W	RCA 2N3525
240V	7A	3AB-7A	RCA 1N3756	100K, 1/2W	RCA 2N3670

TABLE III COMPONENT VALUES FOR FIGURE 7

imum conduction angle occurs at the peak of the sine wave and is restricted to 90°. Increasing conduction angles occur when the gate bias to the SCR is increased to allow firing at voltage values less than the peak value of the voltage at the center tap of the potentiometer.

At no load and low speed, skip cycling operation occurs. This results in erratic motor speeds. Since no counter EMF is induced in the armature when the motor is standing still, the SCR will fire at low bias settings (potentiometer) causing the motor to accelerate to a point where the

counter EMF induced in the rotating armature exceeds the gate firing bias of the SCR and prevents the SCR from firing. The SCR is not able to fire again until the speed of the motor has reduced due to friction losses, to a value where the induced voltage in the rotating armature is less than the gate bias. At this time the SCR fires again. Because the motor deceleration occurs over a number of cycles, there is no voltage applied to the motor hence, the term skip cycling.

When a load is applied to the motor, its speed decreases thereby reducing the counter EMF induced

VAC	IAC	F-1	CR1, CR2	R1	R2	SCR1
120V	1A	3AG-1.5A, Quick Act	RCA 1N3755	5.6K, 2W	1K, 2W	RCA 2N3528
120V	3A	3AB-3A	RCA 1N3755	5.6K, 2W	1K, 2W	RCA 2N3228
120V	7A	3AB-7A	RCA 1N3755	2.7K, 4W	500, 2W	RCA 2N3669
240V	1A	3AG-1.5A, Quick Act	RCA 1N3756	10K, 5W	1K, 2W	RCA 2N3529
240V	3A	3AB-3A	RCA 1N3756	10K, 5W	1K, 2W	RCA 2N3525
240V	7A	3AB-7A	RCA 1N3756	5.6K, 7.5W	500, 2W	RCA 2N3670

TABLE IV COMPONENT VALUES FOR FIGURE 8

a wide range of stable speeds can be obtained without any rewiring of the motor. Since the motor current is a function of the motor itself, resistor R7 has to be matched with the motor rating to provide the necessary feedback for proper load compensation. Resistor R7 may range in value from .1 ohm for larger size motors to 1 ohm for the smaller motors. Circuit values (Fig. 9) for use with the various RCA SCR's are shown in Table V.

When the voltage on C1 reaches the breakdown potential of the neon lamp on the positive half cycle, the neon lamp fires allowing C1 to discharge to the maintaining voltage of the neon lamp through CR1 and neon lamp into the gate of SCR2. When SCR2 fires, the voltage across the control circuit reduces to the forward voltage drop of the SCR allowing C1 to discharge. On the next half-cycle, C1 will charge from a lower positive potential, allowing the neon

lamp to fire earlier in the cycle. The potentiometer may now be increased and still fire the SCR's at a reduced conduction angle, producing the hysteresis effect. On the negative half-cycle, when the charge on C1 has reached the breakdown potential of the neon lamp, the capacitor discharges through CR2, the neon lamp and the primary of transformer T1 to the maintaining voltage of the neon lamp. The current pulse formed by the discharge of C1 is coupled by T1 into the gate of SCR1. For 60-cycle operation, the transformer is not critical since the magnitude and shape of the current firing pulse is determined primarily by the charge on the capacitor and the characteristics of the neon lamp. When different SCR's are used, the load capabilities of the circuit should be observed as shown in table VI.

Conduction angles for the circuit shown vary from approximately 30° to 150° and at the maximum conduction angle, the voltage impressed upon the universal motor is approximately 95 per cent of the input RMS voltage.

A full-wave circuit using the fast switching characteristics of transistors for triggering is shown in Figure 11. By using the transistor network as a low voltage threshold device, maximum con-

VAC	IAC	F-1	CR1	R-1	SCR1
120V	1A	3AG-1.5A, Quick Act	RCA 1N3755	75K, 1/2W	RCA 2N3528
120V	3A	3AB-3A	RCA 1N3755	75K, 1/2W	RCA 2N3228
120V	7A	3AB-7A	RCA 1N3755	75K, 1/2W	RCA 2N3669
240V	1A	3AG-1.5A, Quick Act	RCA 1N3756	150K, 1/2W	RCA 2N3529
240V	3A	3AB-3A	RCA 1N3756	150K, 1/2W	RCA 2N3525
240V	7A	3AB-7A	RCA 1N3756	150K, 1/2W	RCA 2N3670

TABLE V COMPONENT VALUES FOR FIGURE 9

Full Wave

A very simple but effective circuit for full-wave proportional control is shown in Figure 10. This circuit uses the principle of a.c. phase shifting and neon lamp triggering to provide phase angle control. It has the advantage of a symmetrical output for both halves of the a.c. input voltage since the same electrical components are used in the phase shifting and threshold functions for firing the SCR's. Since the SCR gate circuits are completely isolated from each other, the "cross talk" problem usually associated with gate firing circuits using transformer coupling and bi-directional trigger devices is eliminated. Because C1 charges to alternate positive and negative values, there is a hysteresis effect associated with this circuit. With decreasing resistances of R2 from its maximum value, C1 will charge to a higher voltage on each half cycle.

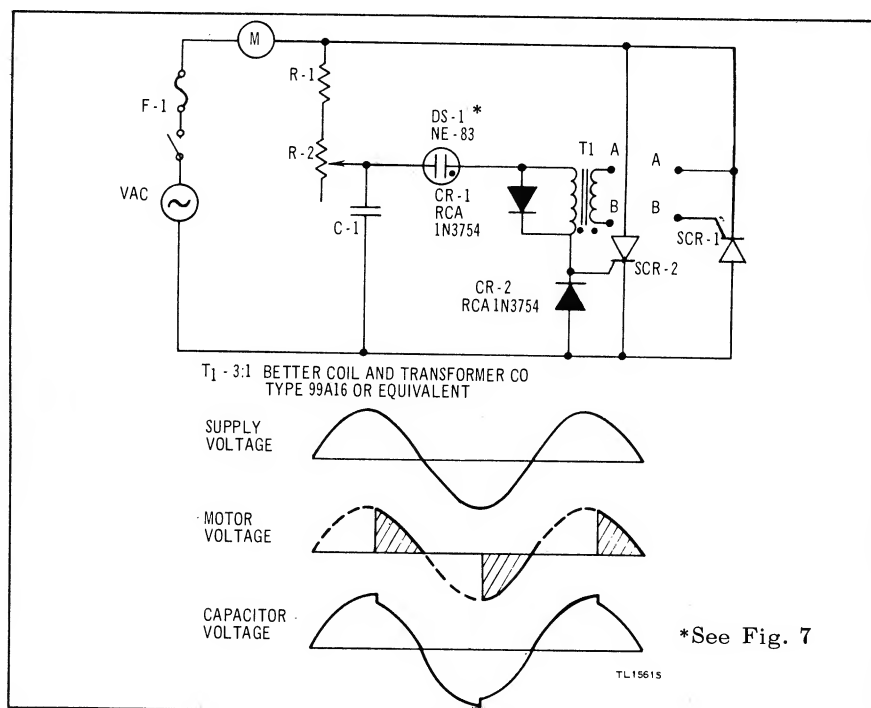


FIGURE 10 FULL-WAVE MOTOR CONTROL, NO REGULATION



VAC	IAC	F-1	R-1	R-2	C	SCR
120V	1.5A	3AG-2A, Quick Act	1K, ½W	50K, ½W	.22μf, 100V	RCA 2N3528
120V	5A	3AB-5A	1K, ½W	50K, ½W	.22μf, 100V	RCA 2N3228
120V	10A	3AB-10A	1K, ½W	25K, 2W	.47μf, 100V	RCA 2N3669
240V	1.5A	3AG-2A, Quick Act	1K, 1W	50K, 2W	.22μf, 100V	RCA 2N3529
240V	5A	3AB-5A	1K, 1W	50K, 2W	.22μf, 100V	RCA 2N3525
240V	10A	3AB-10A	1K, 1W	25K, 4W	.47μf, 100V	RCA 2N3670

TABLE VI COMPONENT VALUES FOR FIGURE 10

duction angle is obtained. The threshold point of the transistor circuit can be changed by varying the value of R3. The phase shift network of R1, R2, and C1 permits the variation of conduction angles from minimum to maximum. An a.c. potential is impressed upon the phaseshifting network to eliminate skip cycling at low conduction angles. The bridge network of CR1, CR2, CR3, and CR4 rectifies the a.c. voltage developed across C1 and provides d.c. voltage to the switching transistors. When the transistors are turned on, capacitor C1 discharges through the saturated transistors into the primary of T1. The pulse formed by C1 and T1 fires the SCR which has a positive potential at the anode since both SCR's receive the same gate polarity pulse. When the SCR fires, the remaining portion of the half-cycle is applied to the load. On the alternate half-cycle, the other SCR will have a positive potential at its anode and will turn on when the gate firing pulse is developed in the primary of T1. Variations in conduction angle are accomplished by changing the setting of R2. With the values shown in Figure 11, the threshold voltage for firing the transistor circuit is approximately 8-volts. A maximum conduction angle of approximately 170° can be achieved with this circuit. Load values for the circuit using different RCA SCR's and voltage inputs are shown in Table VII.

A full-wave circuit designed for applications requiring feedback for compensation of load changes, is shown in Figure 12. Operation is the same as that described for Figure 9 with the exception of full-cycle conduction. In this circuit, R7 should be matched to the characteristics of the specific motor application. The resistor will vary in range from .1 to 1 ohm. Circuit values (Fig. 12) for use with the various RCA SCR's are shown in Table VIII.

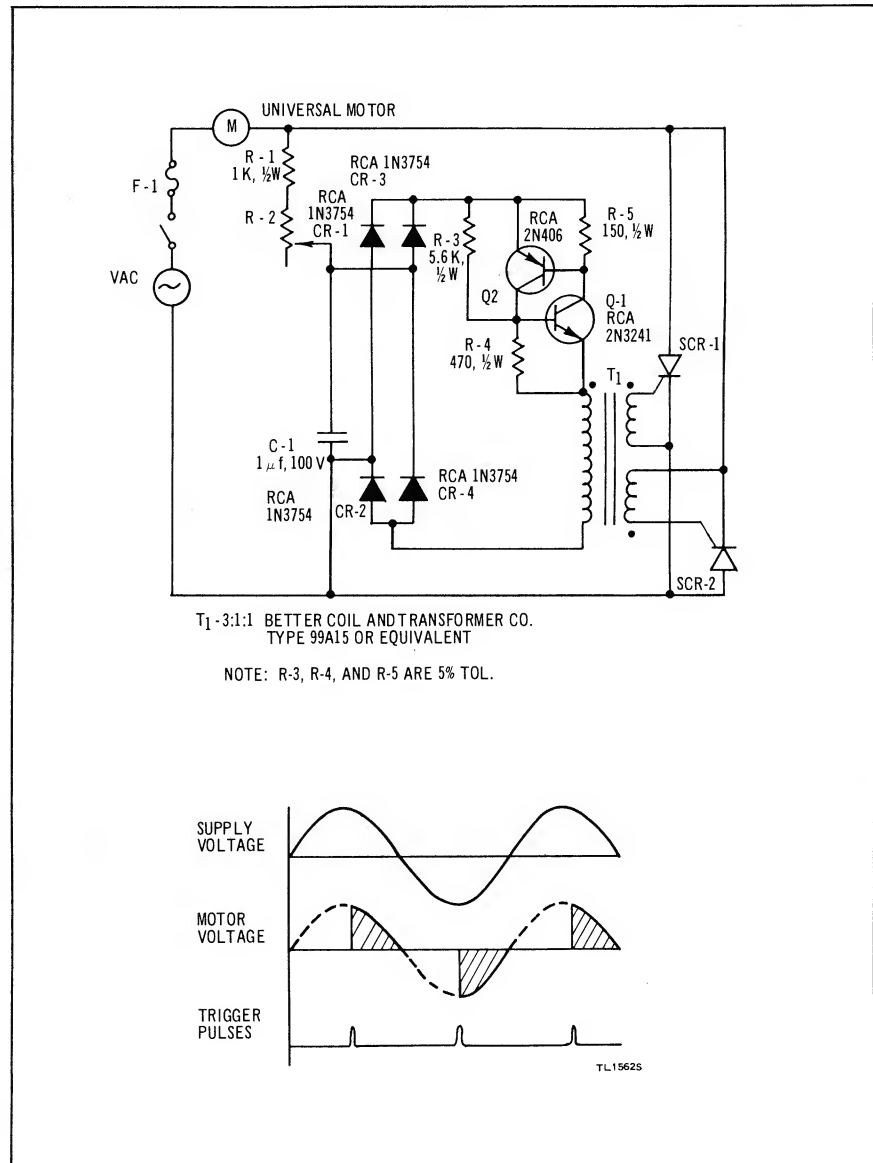


FIGURE 11 FULL-WAVE MOTOR CONTROL, NO REGULATION

VAC	IAC	F-1	R2	SCR1 & SCR2
120V	1.5A	3AG-2A, Quick Act	75K, ½W	RCA 2N3528
120V	5A	3AB-5A	75K, ½W	RCA 2N3228
120V	10A	3AB-10A	75K, ½W	RCA 2N3669
240V	1.5A	3AG-2A, Quick Act	150K, ½W	RCA 2N3529
240V	5A	3AB-5A	150K, ½W	RCA 2N3525
240V	10A	3AB-10A	150K, ½W	RCA 2N3670

TABLE VII COMPONENT VALUES FOR FIGURE 11

For an input voltage (VAC) of 120-volts, the RMS input current calculation becomes:

$$\text{RMS Current} = \text{Horse Power} \times 12.4$$

For an input voltage (VAC) of 240 volts, the RMS input current calculation becomes:

$$\text{RMS Current} = \text{Horse Power} \times 6.2$$

The RMS current calculated from the above formulae should not exceed the values given in the Tables for the various circuits in this Note. The circuits and ratings in

this Universal Motor Applications Note will accommodate motor sizes up to 3/4 horse power at 120V input and up to 1 1/2 horse power at 240 Volts input.

CONCLUSIONS

In the operation of universal motors under normal usage, the versatility of speed control provides many different applications for the user. Several methods of speed control were presented in this Note. The emphasis for the circuits was on simplicity and economy. A higher degree of speed

regulation can be achieved by using more complex firing and feedback circuits. The performance of the circuits will be adequate for a large number of motor applications. Depending upon the individual needs of the user, either half-wave or full-wave, with or without feedback can be selected. A convenient method of speed control is to use the half-wave circuits for the variable speed control and by-pass the SCR and its control circuitry with a switch for full power operation.

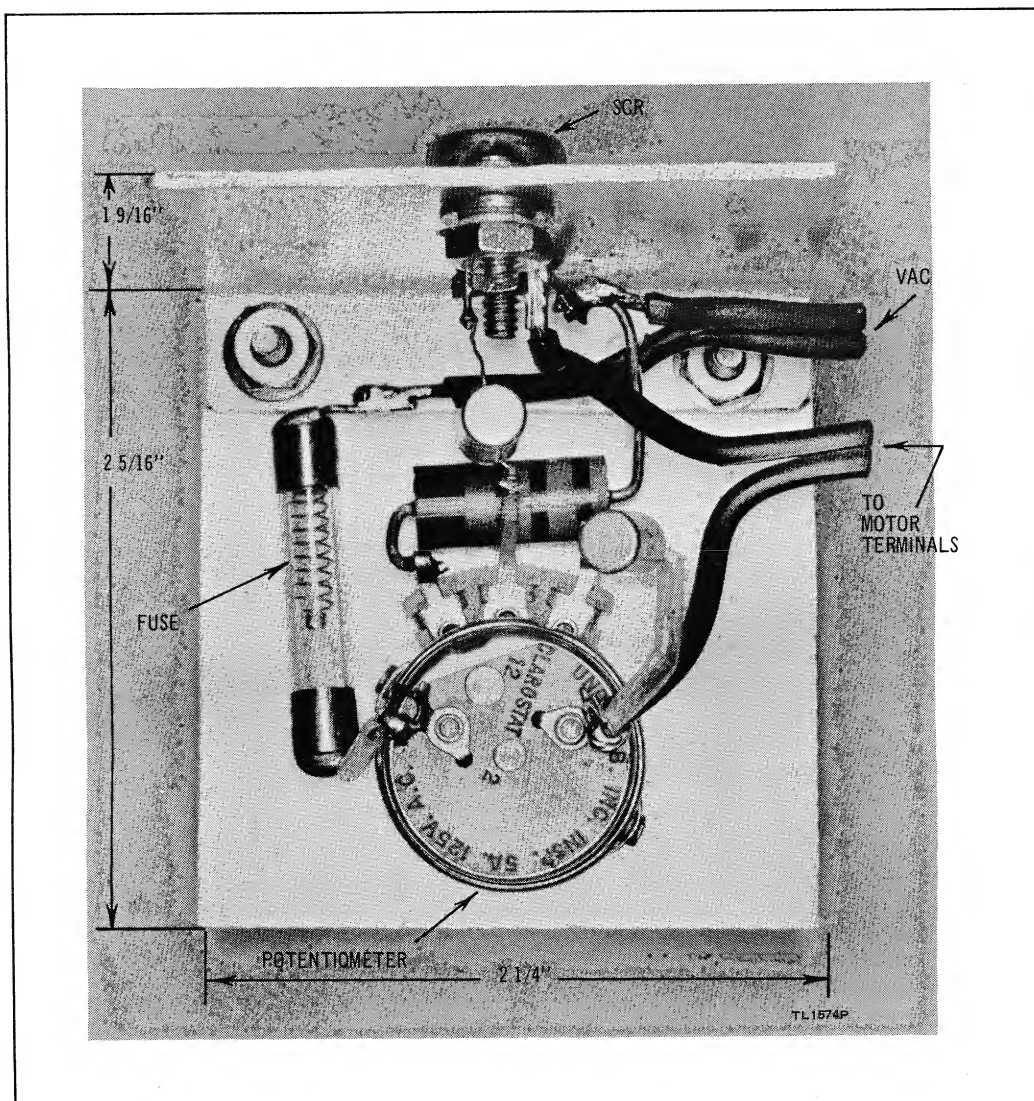


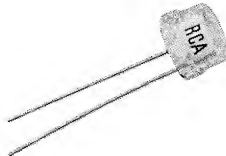
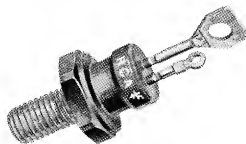
FIGURE 13 HALF-WAVE MOTOR SPEED CONTROL



The following RCA SCR's, referred to in this SMA-38, are completely characterized on separate technical bulletins, available upon request. A quick recap is given in the following chart.

RCA SCR TYPE NO.	AC LINE VOLTAGE	DEVICE CURRENT RATING (RMS AMPS)	JEDEC PACKAGE	
2N3669	120V	12.5 @ $T_C = 80^\circ\text{C}$		TO-3
2N3670	240V	12.5 @ $T_C = 80^\circ\text{C}$		
2N3528	120V	2.0 @ $T_{FA} = 25^\circ\text{C}$		TO-8
2N3529	240V	2.0 @ $T_{FA} = 25^\circ\text{C}$		
2N3228	120V	5.0 @ $T_C = 75^\circ\text{C}$		TO-66
2N3525	240V	5.0 @ $T_C = 75^\circ\text{C}$		

In addition to the foregoing, RCA also offers additional SCR types:

RCA SCR TYPE NO.	AMPS		VOLTS (V _{RM})	JEDEC PACKAGE		
	AVG.	RMS				
TA2682	1.6	2.5	200 (120V Line)		TO-5	
TA2683	1.6	2.5	400 (240V Line)			
2N681-2N690	16	25	25-600		TO-48	
2N1842A-2N1850A	10	16	25-500			
2N1770-2N1778	4.7	7.4	25-500V		TO-64	
TA2652 TA2653 TA2654 TA2655	Inverter Types	3.2	5.0	100		TO-66
		3.2	5.0	200		
		3.2	5.0	400		
		3.2	5.0	600		
TA2442	18	28	100		Press Fit	
TA2444	18	28	200 (120V Line)			
TA2447	18	28	400 (240V Line)			



RADIO CORPORATION OF AMERICA

ELECTRONIC COMPONENTS AND DEVICES, HARRISON, N.J.

Trademark(s) ® Registered
Marca(s) Registrada(s)

© 1965 by Radio Corporation of America
All rights reserved.

3-65
Printed in U.S.A.

RCA ELECTRONIC COMPONENTS & DEVICES, EAST-NEWARK, N.J. 07102, 32 GREEN STREET, (201) 485-9900 • SYRACUSE, N.Y. 13203, 731 JAMES ST., ROOM 402, (315) 474-5591 • HADDONFIELD, N.J. 08034, 605 MARLTON PIKE, (609) 428-4802 • GREATER BALTIMORE AREA, 1725 "K" STREET, N.W. WASHINGTON 6, D.C., FE7-8500 • NORTHEAST: NEEDHAM HEIGHTS, MASS. 02194, 64 "A" ST., (617) 444-7200 • SOUTHEAST: ORLANDO, FLA. 32803, 200 EAST MARKS ST., (305) 425-5563 • CENTRAL: CHICAGO, ILL. 60618, 496 EAST HOWARD AVE. DES PLAINES, (312) 827-5033 • DALLAS, TEXAS 7501, CARPENTER FREEWAY, ME1-3030 • INDIANAPOLIS, IND. 46209, 2511 EAST W ST., BLDG. CO, ATKINSON SQ., (317) 546-4001 • MINNEAPOLIS, MINN., 55416, 5805 EXCELSIOR BLVD., (612) 929-0676 • DETROIT, MICH., 48202, 714 NEW CENTER BLDG., (313) 875-5600 • WEST: LOS ALTOS, CALIF., 94022, 4546 EL CAMINO REAL, SUITE P, (415) 948-8996 • HOLLYWOOD, CALIF., 2008-6363 SUNSET BLVD., (213) 461-9171 • SEATTLE, WASH., 98104, 2246 FIRST AVE. SOUTH, (206) MAIN-2-8816 • GOVERNMENT: DAYTON, OHIO 45402, 224 N. WILKINSON ST., (512) 461-5480 • HARRISON, N.J. 07029, 415 S. FIFTH ST., (201) 485-3900 • WASHINGTON, D.C. 20006, 1725 "K" ST., N.W., (202) 337-4500 • RCA INTERNATIONAL DIVISION: CLARK, N.J., 07066, CENTRAL AND TERMINAL AVES., (201) 382-1000